한국정보전자통신기술학회논문지(jkiiect)'16-12, Vol.9 No.6
논문 16-09-06-519 http://dx.doi.org/10.17661/jkiiect.2016.9.6.519

A Fast Algorithm for Region-Oriented Texture Coding

Young-Gyu Choi*, Chong-Hwan Choi**, Ha-Young Cheong***

Abstract This paper addresses the framework of object-oriented image coding, describing a new algorithm, based on monodimensional Legendre polynomials, for texture approximation. Through the use of 1D orthogonal basis functions, the computational complexity which usually makes prohibitive most of 2D region-oriented approaches is significantly reduced, while only a slight increment of distortion is introduced. In the aim of preserving the bidimensional intersample correlation of the texture information as much as possible, suitable pseudo-bidimensional basis functions have been used, yielding significant improvements with respect to the straightforward 1D approach. The algorithm has been experimented for coding still images as well as motion compensated sequences, showing interesting possibilities of application for very low bitrate video coding.

Key Words : Image coding, Region-oriented, 1D approach, 2D region-oriented video coding, Texture approximation

1. Introduction

The idea of using object-oriented approaches for efficient coding of images and sequences has inspired almost all the so-called "second generation" techniques[1-8], based on the shared opinion that any effective video compression necessarily relies on a preliminary good image segmentation.

The standardization process, both in real-time[9] and interactive [10] visual communication, has strongly recommended the universality of the proposed techniques the intrinsic characteristics of the scene (real edges, 3D objects structure, texture- homogeneous regions, etc.) are substantially ignored.

On the other hand, application-oriented approaches are drawing more and more attention to very low bitrate communications where the specific visual information can be efficiently formalized, modeled and predicted. Videophone sequences, in particular, identify an easy-to-model class of images, suitable to object-oriented processing for high compression coding. Different methodologies have been proposed to exploit the a priori knowledge and to design the appropriate scene model, depending on the aimed compression, complexity and quality. These methodologies, however, usually address the problem from a too specific point of view without the necessary requirement of generality.

The on-goin activities fo the MPEG group are presently facing the prdblm of driving the short-term research towards new algorithms and techniques for very low bitrate coding of moving pictures, and a new standard MPEG-4

*Department of Computer Engineering, Korea National University of Transportation
**Department Aerodefense&Information Communication, Daeduk College
***Corresponding Author : Head of research center, Corporation e-oasis(chy5225@naver.com)
Received November 24, 2016 Revised November 29, 2016 Accepted December 26, 2016

is expected in 1998 [11].

2. 2D Orthogonal Basis Functions

The Gram-schmidt procedure, or the Householder procedure, have been recently used by Gilge et al. [10] to obtain a set of orthogonal bidimensional functions starting from set of independent polynomials. Since these orthogonal functions depend exclusively on the geometry of the specific region, they can be implicitely computed at the decoder just after having reconstructed the region contour. Differently from polynomial approximation techniques, where at each variation of the polynomial order all the coefficients must be recomputed, the use of orthogonal functions keeps them unchanged. This allows an easy control of the approximation error, which can be reduced to a whatever extent by adding new basis functions without altering the previously computed coefficients.

These significant advantages are however paid in therms of the computational overhead due to the orthogonalization procedures: for each region many high-precision operations, involving high-dimensional vectors,are executed. This complexity is actually affordable only in case of small regions, thus becoming prohibitive for real-time applications.

3. The Dicrete Legendre Polynomial

Applying the “Gram-Schmidt” procedure to the set of independednt polynomials S= 1, t, t^2,t^3, ⋯ in the interval [-1,1], the so-called “Legender” polynomials are obtained whose fast computation can be implemented by means of well-known recursive equations.

Through a novel mathematical formalism, the “Legendre” recursive equations have been extended from the continuous to the discrete domain and a fast orthogonalization algorithm has been defined whose basic results are summarized in the following. Let us consider a region with M pixel area, whose texture has been converted into an M pixel sequence of samples.

let p_n(t)be the generic n-th order polynomial defined in the interval [0, ⋯, M-1] and let $||Pn||^2$ be the norm of Pn(t) computed as:

$$\|p_n\|^2 = \sum_{t=0}^{M-1} pn(t)\cdot pn(t) \tag{1}$$

The discrete recursive equations result:

$$\begin{cases} p_0(t) = 1 \\ p_1(t) = t - \dfrac{(M-1)}{2} \\ \cdots \quad \cdots \quad \cdots \\ p_0(t) = p_1(t)\cdot p_{n-1}(t) - \dfrac{\|p_{n-1}\|}{\|p_{n-2}\|}\cdot p_{n-2}(t) \end{cases} \tag{2}$$

and the coefficients are consequently computed as:

$$c_n = \frac{\sum_{t=0}^{M-1} g(t)\cdot p_n(t)}{\|p_n\|^2} \tag{3}$$

where g(t) represents the 1D texture waveform to be approximated.

4. A Fast Algoritth For Texture Approximation

Our approach employs a new algorithm for texture coding, based on orthogonal basis functions, capable to provide appreciable rate-distortion performances with very low complexity

As opposed to the 2D approach, the algorithm we have developed decimates the encoding complexity by means of two operations: I) the region is scanned along low-entropy paths to convert its texture into monodi-mensional waveforms; ii) the so obtained waveforms are approximated by means of 1D orthogonal functions.

To odtain a smooth representation of the texture information, the scanning path must maximize the in tersample correlation. Based on previous studies [12], different solutions have been invioustigated for the geometry of the scanning path like spiral or zig-zag paths.

Experimental results have shown that the approximation quality is generally very low and most of times independent of the particular scanning path. This means that the monodimensional representation of the texture information evidently reduces data correlation to an unacceptable degree, unsuited to low order polynomial approximation.

To partially regain the lost bidimensional inter-sample correlation, a trade-off solution between the 2D and the 1D approach has been devised, thying to prserve as much as possidle the good characteristics of both of them, i.e. the good approximation capability of the former and the low complexity of the latter. A satisfactory answer to this erquirement has been found out by means of what we call "pseudo-bidimensional" orthogonal basis functions. As shown in Figure 1, each row of the region is considered separately as an independent subregion. The 0-th order Legendre polynomials p_0^i(t) are computed for each i-th row of the region and are combined together to form the 0-th order 2D function F_0. the same procedure is further applied to compute the higher order Legendre polynomials of each row and to dbtain the corresponding functions F_1, $F_2, \cdots F_n$, where n is the maximum approximation order.

Functions F_i and $F_j \forall i,i \in [0,n]$, being orthogonal row by row, are consequently orthogonal also in the 2D domain where they represent a valid set of orthogonal basis functions. Although it is arbitrary to scan the region along the rows rather than along the columns, it is preferable to choose the direction of the region maximum extension: the longer is the 1D sequence the higher is number of orthogonal polynomials which can be employed for its approximation. In case of a predominant horizontal extension of the region, the following operations are performed:

1. the region is scanned along the direction of the reow;
2. a set S_1 of pseudo-bidimensional functions is obtained;
3. the region texture is approximated and a set C_1 of coefficients is obtained;
4. the region texture is replaced with the approximation error;
5. the region is scanned along the direction of the columns;
6. a set S_2 of pseudo-bidimensional functions is obtained;
7. the error is approximated and a set C_2 of coefficients is obtained;
8. coefficients C_1 and C_2 are coded.

The isformation on the first scanning

direction, as well as the parameters of the pseudo-bidimensional basis functions in S_1 and S_2, can be derived directly from the region contour and do not require to be coded.

5. Expermimental Results

The algorithm complexity, as shown in Table 1, is significantly reduced with respect to the 2D orthogonalization procedure proposed by Gilge et al. [13], passing from a quadratic dependence on the number n of coefficients per region, to a linear dependence.

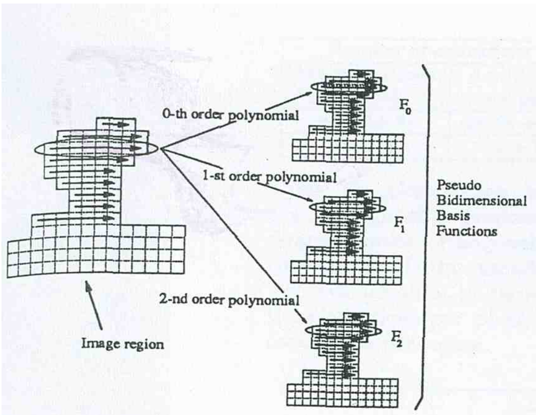

Fig. 1. Pseudo-bidimensional basis functions are obtained by combining, row by row, 1D orthogonal Legendre poltnomials.

The number of operations per poxel does not depend on the region area, but exclusively on the number n of coefficients per region. In the example of Figure 2 the gray-level image "Pepper" has been coded and reconstructed employing both the Gilge 2D approach and the novel 1D algorithm. From the experimental results it comes out that only a slight loss in the rate-distortion performances id paid in exchange of the significant complexity reduction. The rate-distortion performances, obtained by varying the coding parameters, have been computed to test the algorithm sensitivity with respect to the number of regions, number of coefficients per region and quantization bits per coefficient. the corresponding curbes are plotted in Figures 3, 4 and 5, respectively. the novel algorithm has been successfully applied for encoding the prediction error within a conventional motion compensation scheme for video coding. The preliminary experimental results show the concrete possibility of its application for very low speed video communication. The preliminary experimental results show the concrete possibility of its application for very low speed video communication. In Table 2 the results obtained by applying the algorithm to the videophone sequence "Salesman" are presented.

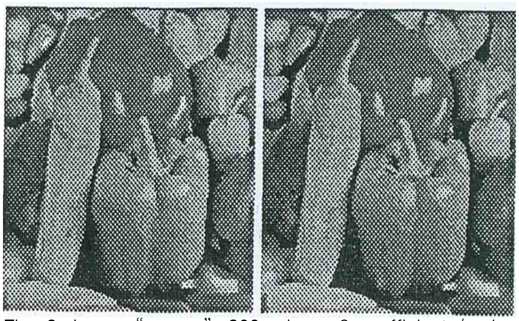

Fig. 2. Image "pepper", 200regions, 6 coefficients/region, 8bits/coefficients. (Left) Reconstruction through 1D orthogonal functions at 0.51 bpp with PSNR=25.75. (Right) Reconstruction by means of the 2D algorithm (Gilge) with 2D orthogonal functions, at 0.49 bpp with PSNR=25.98.

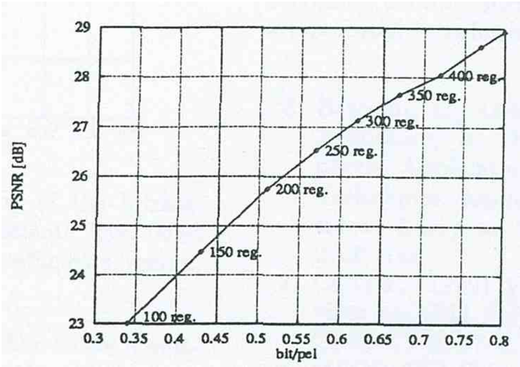

Fig. 3 PSNR curve as a function of the bitrate, with increasing number of regions. Evaluated on “pepper” with 6 coefficients/region, 8 bits/coefficient.

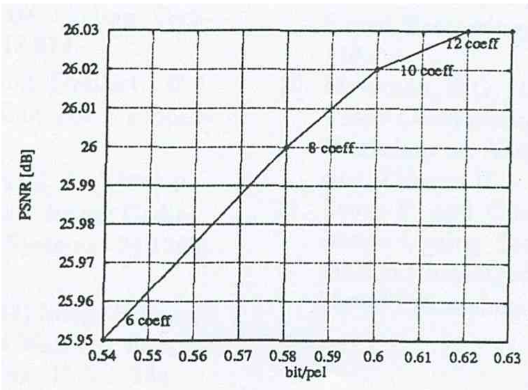

Fig. 4 PSNR curve as a function of the bitrate, with increasing number of coefficients/region. Evaluated on “pepper” with 200 region, 8 bits/coefficient.

Number of operations		Coding
Multiplications per pel	Additions per pel	Algorithm
$n(2n+3)$	$2n(n+1)$	2D orthogonalization
$5n-6$	$3n+1$	1D orthogonalization

Table 1: Comparison between the complexoty of the 2D algorithm proposed by Gilge, employing the Gram-Schmidt orthogonalization procedure, and the complexity of the pseudo-bidimensional algorithm. The evaluation is in therms of number of multiplications/additions per pixel, where n is the number of coefficinets per region.

frame	regions	bpp	% b_t	% b_c	% b_m	PSNR
22	43	0.115	22.91	37.77	39.31	30.68
24	46	0.104	26.23	42.68	31.09	30.71
26	43	0.106	23.84	41.31	34.84	30.77
28	41	0.108	21.59	36.58	41.82	30.46
30	39	0.106	21.16	30.31	48.52	30.55
32	43	0.118	21.32	37.24	41.43	30.49
34	44	0.120	19.05	41.46	39.49	30.65
36	43	0.106	24.35	37.81	37.83	30.66
38	36	0.092	23.86	34.44	41.69	30.79
40	37	0.093	22.02	36.56	41.41	30.69

Table 2: Performances evaluated on the sequence Salesman, Luminance only, format 256x256, 15 frames/second. Images have been motion compensated and the prediction error has been coded through the region-baded algorithm. The frame in column 2 while the bitrate and PSNR are reported in columns 3 and 6, respectively. The bitrate percentage due to texture encoding, contour encoding and motion field encoding are reported in columns 3,4 and 5, respectivelt.

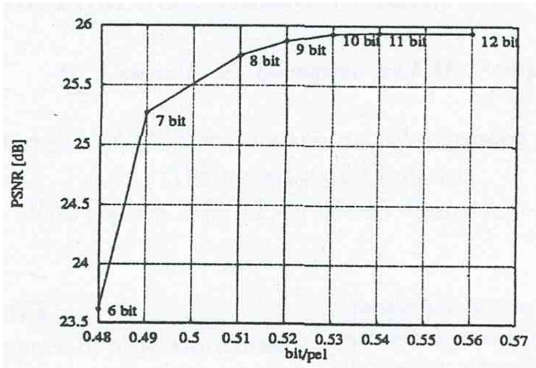

Fig. 5 Psnr curve as a function of the bitrate, with increading number of bits/coefficient. Evaluated on “pepper” with 200 region and 6 coefficients/region.

6. Conclusions

A new method for high compression image coding has been described, based on discrete Legendre polynomials, capable to approximate natural textures with acceptable quality and fast computation. The algorithm sensitivity to variations in the number of regions, in the order of the polynomials and in the quantization precision has been further investigated and the achieved results are reported and discussed. The method has been compared to recently proposed similar 2D approaches showing ednsible improvements, as complexity is concerned, for coding both still and moving pictures. The overall characteristics of the method make it suitable for real-time video coding at very low bitrate

REFERENCES

[1] Kunt, M., Ikonomopoulos, A. and Kocher, M.(1999) Second-Generation Image Coding Techniques, IEEE Proceedings 73:549-574.

[2] Musmann, H.G., Pirsh, P. and Grallert, H.J.(2000) Advances in Picture Coding, IEEE Procedings, 73:523-548.

[3] Kunt, M., Benard, M. and Leonardi, R. (2001) Recent Results in High-Compression Image Coding, IEEE trans. on Circuits and Systems, 34:1306-1336.

[4] Hoetter, M. and Thoma, R. (2001) Image Segmentation Based on Object Oriented Mappong Parameter Estimation, Signal Processing, 15:315-334.

[5] Musmann, H.H., Hoetter, M. and Ostermann, J.(2004) Object-Oriented Analysis-Synthesis Coding of Moving Images, Signal Processing: Image Communication, 1:117-138.

[6] Braccini, C., Grattarola, A., Lavagetto, F. and Zappatore, S. (2004) “VQ Coding for Videophone Applications Adopting Knowledge-Based Techniques: Implementation on Pa allel Architectures:, European Trans. on Telecommunications, 3:137-144.

[7] S.H. Park, T.J. Jeon, S.H. Kim, S.Y. Lee, J.W. Kim, “Deep learning based symbol recognition for the visually, impaired,” Journal of Korea institute of information, electronics, and communication technology 9(3), pp.249-256, 2016.

[8] B.-J. Park, K.-Y. Kim, S.-J. Kim, " Study on Face recognition algorithm using the eye detection", Journal of Korea institute of information, electronics, and communication technology vol. 8, no. 6 pp.491 - 496, 2015.

[9] CCITT, (2005) Video codec for audiovisual services at p*64 kbits/s”, Recommendation H.261, CDM XV_R 37_E.

[10] Gilge, m., Engelhardt, T. and Melhan, R. (2006) Coding of Arbitrarily Shaped Image Segments Based on a Generalized Orthogonal Transform, Signal Processing: Image Communication, 1:103-116.

[11] Mussman, H.G. (2007) A Unified Point of View on Video Compression: A Model-based Perspective, Workshop on Very Low Bitrate Video Compression, Urbana IL.

[12] Leou, F. and Chen, C. (2010) A C contour-based Image Coding Technique with its Texture Ingormation Reconstructed by Polyline Reconstructed by Polyline Representation, Signal Processing, 25:81-89

[13] MPEG ISO-IEC JTC 1/SC 29/WG11, (2005) Coding of moving pictures and associated audio for digital storage media up to about 1,5 Mbit/s.

Author Biography

Young-Gyu Choi

- Feb. 1983 : Cheongju University, Electronics Eng., B.S. Degree
- Jul. 1986 : Chungang University, Electronics Eng., Master Degree
- Aug. 1995 : Cheongju University, Electronics Eng., Ph. D. Degree
- May 1991 ~ present : Department of Computer Engineering, Korea National University of Transportation, professor

<Research Interests> IT Convergence System Design

Chong-Hwan Choi

- Feb. 1978 : Myongji University, Electronics Eng., B.S. Degree
- Feb. 1980 : Myongji University, Electronics Eng., Master Degree
- Aug. 1993 : Myongji University, Electronics Eng., Ph. D. Degree
- Mar. 1988 ~ present : Department Aerodefense & Information Communication, Daeduk College, professor

<Research Interests> Signal processing, Big Data

Ha-Young Cheong

- 1984 : Kyonggi University, Department of Industrial Engineering
- 1989 : Hanyang University, Department of Public Administration
- 2010 : Catholic Kwandong University, Department of Electronic Communication Engineering

<Research Interests> Real-time Recognition, Tracking System